UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
Region Eight
Albuquerque, New Mexico

Hugh G. Calkins
Regional Conservator

REPORT ON THE UPPER AND MIDDLE GILA WATERSHED

With Proposals for Erosion Control and Water-Flow Retardation

DISCUSSION OF DAMAGES AND BENEFITS

Regional Bulletin No. 42
Conservation Economics Series No. 15
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#420

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Albuquerque, New Mexico

June 19, 1937

Dr. Austin L. Patrick
Soil Conservation Service
Washington, D. C.

Dear Dr. Patrick:

At the request of the Regional Conservator, I am submitting herewith six copies of a report dealing with the problem of analysis of damages and benefits in connection with the report on the Upper and Middle Gila Watersheds.

In the course of the preparation of this report, it has become necessary to examine the current methods of estimating economic justification for flood control work. In the absence of a uniform procedure for the economic analysis of such proposals, an attempt has been made here to develop a procedure consistent within itself and consistent with elements of public policy contained in the Flood Control Act and in recent legislative action.

Material dealing with the problem of justification of flood control work is contained in a paper recently submitted to the Bureau of Agricultural Economics. A copy of this paper is submitted for review and criticism.

Sincerely yours,

Eshref Shevky
Section of Human Surveys

UNITED STATES
DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Albuquerque, New Mexico

June 19, 1937

Mr. H. G. Calkins
Regional Conservator
Soil Conservation Service
Albuquerque, New Mexico

Dear Mr. Calkins:

Transmitted herewith is a copy of the report dealing with the problems of damage and the calculation of benefits to supplement the Gila Flood Control Report.

Although considerable work has been done in this office dealing with the economic aspects of soil and water conservation, and this work has, more recently, been pursued with greater emphasis in connection with the duties under the Flood Control Act, no valid reason exists at this time for anticipating the procedure ultimately to be adopted for the examination of justification for flood control projects by the Bureau of Agricultural Economics.

The present report contains an examination of the available record of flood damage in the Upper and Middle Gila Watershed and an evaluation and systematic presentation of this record by categories. The proposals for erosion control and water-flow retardation for the watershed have been related to these categories of damage and a calculation of anticipated benefits has been made. All assumptions and premises have been clearly stated. The emphasis has been placed on providing basic data from which a ratio of average annual benefits to average annual costs may be calculated for purposes of comparison with other flood control projects.

Sincerely yours,

Eshref Shevky
Section of Human Surveys

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INTRODUCTION

This report which attempts to measure the economic justification of the proposed Gila Flood Control Project faces two principal obstacles. First, the proposals relating to trunk stream structures which the Army Corps of Engineers are expected to submit are not at hand at the time of the writing of this report. Estimates of costs and estimates of the degree of effectiveness of that phase of the program are, therefore, largely conjectural. Second, although estimates of costs are at hand for that portion of the program recommended by the Department of Agriculture, data on the probable degree of effectiveness of the various elements of the program lack sufficient definition for purposes of estimating benefits. In the face of these two obstacles a report on the economic justification of the proposed project is severely limited.

Certain other deficiencies in basic data further limit the adequacy and significance of this attempt to measure economic justification. These are deficiencies common to all such attempts. They have been discussed in detail elsewhere (1) but may be mentioned here. They include the fact that public policy has not yet defined the concept of benefit, nor the basic premises

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(1) "Notes on the Justification of Flood Control Proposals" submitted to the Bureau of Agricultural Economics, June, 1937.

upon which estimates of economic justification must rest; deficiencies in the techniques for making such estimates; and deficiencies in the flood-damage data available on the Gila Drainage Area.

Deficiencies in the data on damage necessitate the use of certain doubtful assumptions. These include assumptions as to damages in the past and assumptions as to probable future damages if no flood protection work is undertaken.

It is necessary to assume that the data available on past damages are complete and reasonably accurate. There is definite evidence, however, to indicate that they are not complete, though the extent of their incompleteness cannot be accurately judged. That they are subject to a wide margin of error is immediately evident upon examination of the basic data which relies to a large extent upon rather tenuous estimates. This is a deficiency for which there is no remedy. The requisite data simply do not exist. This deficiency is not peculiar to the Gila Report, but is probably present in every flood control report. The degree of deficiency in this respect in this instance, however, may be somewhat greater than usual.

The difficulties relating to the projection of future damages on the basis of damages experienced in the past are also common to all flood-control reports. In this instance, as well as in every other, however, it would be desirable, though

it may be impossible, to have evidence on the basis of which such project might be legitimately made. In this report there is an absence of this type of evidence in regard to damage to lands, to railroads, to highways, etc. Data on the relationship of floods on the Gila to the lower Colorado system are also absent. A category of benefits in terms of prevention of possible damage to the Yuma and Imperial Valley areas is therefore not susceptible of evaluation.

FLOODS IN THE UPPER AND MIDDLE GILA WATERSHED

The following tabulation summarizes flood damages in the Upper and Middle Gila Watershed in the thirty-year period, 1907 to 1936, as reported by the Weather Bureau, the only official agency which has attempted complete reporting.

FLOODS: GILA RIVER WATERSHED

1907 - 1937

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1907	-	-	-	- (2)	$ -
1908	Feb. 4	Gila	-	First flood warning issued.	-
1909	-	-	-	-	-
1910	Aug. 30	San Pedro	-	At Fairbanks: river overflowed its banks for 20 miles, washing out railroads and devastating farms. (2)	-
1911	March 7-8	Gila	8 ft.	-	-
1911	July 26	Gila	10 ft.	-	-
1911	Sept. 15	Gila	7 ft.	-	-
1911	Oct. 7	Gila	7 ft.	-	-
1912	March 12	Gila	16 ft.	Diversion dam washed out (3)	-
1912	April	Gila, Salt, and Verde	-	High water interrupted traffic; streams unfordable. (1)	-
1912	July 25	Gila	10 ft.	-	-

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1912	July 30	Gila	8 ft.	-	-
1912	Aug. 31	Gila	8 ft.	-	-
1913	Feb. 27	Gila	6 ft.	-	-
1914	July 20-31	Gila	3 ft.	-	-
1914	Aug. 19, 23	Gila	5 and 4 ft.	-	-
1914	Sept. 21	Gila	4 ft.	Mining town of Ray flooded; considerable property damage. (3)	-
1914	Oct. 6	Gila	5 ft.	-	-
1914	Nov. 13	Gila	4 ft.	-	-
1914	Dec. 20-21	Gila	13 ft.	-	-
1914	Dec. 24	Gila	14 ft.	Damage to bridges, diversion dams; interference with securing and marketing of crops	-(3)
1915	Jan. 31	Gila	12 ft.	Chiefly from Salt River. Destruction of crops, erosion on bottom lands; damages to bridges, dams, interference with traffic.(3)	-
1915	Feb. 12	Gila	5 ft.	No freshets. (3)	-
1915	Feb. 21	Gila	8 ft.	No freshets. (3)	-
1915	March 24,27	Gila	5 ft.	No freshets. (3)	-

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1915	April 1, 8	Gila	5 ft.	No freshets. (3)	-
1915	Apr. 18-19	Gila	4 ft.	No freshets. (3)	-
1915	July 27	Gila	7 ft.	-	-
1916	Jan. 20,29	Gila	20 and 10 ft.	Property loss to bridges, irrigation works agricultural land on Gila and tributaries estimated at -- highest water marks since 1891. Estimated damage to agricultural land in whole state $221,000; to whole lower Colorado watershed (Cal. & Ariz.) $7,603,686. (2)	$305,000 (3)
1916	March 2	Gila	5 ft.	-	-
1916	March 24	Gila	5 ft.	-	-
1916	Oct. 15	Gila	12 and 14 ft.	Freshets. (3)	-
1917	Jan. 22	Gila	7 ft.	Freshets without damage. (3)	-
1918	Aug. 6, 7	Gila	8 and 5 ft.	Chiefly from the Salt River where irrigation works were damaged and farms flooded. (3)	-
1919	July 6, 16, 28	Gila, San Pedro	5, 7, and 5 ft.	At Benson, heavy rains washed out roads, caused heavy damage to railroads (including wrecks) and bridges. Damage to San Pedro Irrigation system. (3)	-
1919	Aug. 4	Gila	8 ft. (2)	-	-

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1919	Dec. 5	Gila	10 ft. (2)	-	-
1920	Feb. 11, 21	Gila & Trib.	6 and 6 ft.	Heavy rains caused sharp rises, damaging roadbeds, bridges. (1)	$314,000
1921	July 28	Gila	6 ft.	River unfordable. (3)	-
1921	Aug. 22	Gila	8 ft.	River unfordable. (3)	-
1922	Aug. 22	Gila	4 ft.	-	-
1923	July 14,23	Gila	7 and 6 ft.	-	-
1923	Aug. 10, 14, 16	Gila	6, 6, & 6 ft.	-	-
1923	Dec. 29	Gila	7 ft.	-	-
1924	April 10	Gila	4 ft.	-	-
1925	August	Gila	5 ft. (2)	-	-
1925	Sept. 4	Gila	7 ft.	Bridge 4 miles from San Carlos washed out, delaying railroad; highway and crop damage near Florence. (3)	-
1925	Dec. 3	Gila	6 ft.	-	-
1926	March 30	Gila	5 ft.	-	-
1926	April 7	Gila	5 ft.	-	-

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1926	Sept. 28	Gila & trib.	16 ft.	Damage chiefly to areas of rainfall on tributaries: S.P. railroads ($375,000), highways ($60,000); Camp Little at Nogales ($12,000). Total damage - (1)	$447,000
				Thatcher and Safford flooded; adobe houses crumpled. (3)	-
1927	Feb. 17, 18	Gila, Salt	-	Flood conditions: 6 ft. crest on Gila, 10 ft. crest on Salt. Damage chiefly to crops on both. (1)	$11,800
1927	Sept. 13	Gila	6 ft. (2)	Severe autumnal flood. One death at Coolidge Dam; railroad tracks washed out between Pima and Central; much overflow on agricultural land. (3)	-
1928	Aug. 2-3	Gila	5 and 7 ft.	-	-
1928	Aug. 28	Gila	5 ft. (2)	-	-
1929	Sept. 24	Gila	8 ft. (2)	Damage to prison at Florence--	$500
				40-hour traffic interference due to railroad and highway washouts near Benson.(3)	-
1930	Aug. 8	Gila, San Pedro	8 and 13 ft.	-	-
1931	Feb. 16	Gila, San Pedro	5 and 6 ft.	Flash rises. (3)	-
1931	Aug. 10,30	Gila, San Pedro	6 and 11 ft.	Flow from San Pedro, chiefly. (3)	-
1931	Oct. 2	Gila	8 ft.	-	-

Year	Date	Watershed	Flood Stage at Kelvin (1)	Description of Damage	Estimated Damage
1932	Feb. 10	Gila	5 ft.	-	-
1932	July			Floods in southeastern part of state	-
1933	July 24	Gila	5 ft.	Damage at Miami. (3)	-
1933	Sept.	Gila, Salt	-	Crops and buildings destroyed near Gilbert.(3)	-
1934	August	Gila	-	Livestock swept away at Duncan. (3)	$1,500
1934	Aug. 27	Gila, San Carlos	-	Rain and flood damage at Globe and Miami: 1 death; stores and homes damaged. (3)	$20,000
1934	Sept. 23	Gila	4 ft.	-	-
1935	Feb. 7	San Carlos	-	Indian dwellings destroyed on San Carlos Reservation near Globe. (3)	-
1935	July 31	Gila	-	Thatcher-Pima area rail and highway traffic disrupted; small homes and city water supply pipelines damaged. (3)	-
1935	Aug. 1	San Carlos	-	Globe-Miami area inundated; roads washed, damage chiefly to Miami and Claypool. (3)	-
1935	Aug. 28	San Pedro	-	Bus hit by wall of water at Dragoon Underpass near Wilcox: 5 deaths	- (3)
1936	July 25	San Pedro	-	Railroad tracks, bridge washed out by rainstorm at Dragoon. (3)	$6,000

(1) Source: FLOODS IN THE UNITED STATES, Magnitude and Frequency; U.S.G.S. Water Supply Paper #771, 1936, page 350; (Gila flood stages, rounded to nearest foot).
(2) Source: MONTHLY WEATHER REVIEW, U.S.W.B. River and Flood Service Reports, 1907 - 1935.
(3) Source: CLIMATOLOGICAL DATA, Arizona Section. U.S.W.B. 1907 - 1937

The total damage upon which a monetary estimate has been placed in the tabulation above is $1,087,000, or over the thirty-year period from 1907 to 1937 an average annual damage of $36,200. Examination of these tabular data indicates clearly that considerable damage occurred of which no monetary estimate was made. The figure of $36,200 does not cover at all completely the flood damages in the watershed. In addition the data are not sufficiently detailed to permit a breakdown into various categories of damage. Another tabulation of damages has therefore been prepared on the basis of information obtained from a wide variety of sources, including local newspapers and residents, local irrigation district records, and land surveys by government agencies. This tabulation and summary follow.

FLOOD DAMAGE IN THE UPPER AND MIDDLE GILA WATERSHED

SUMMARY OF DAMAGES

A. Damage to Railroads

Data on damage to railroads by floods are from two sources:

Southern Pacific Railroad, El Paso Division
$557,293 over the 11 years, 1925-1936.

Southern Pacific Railroad, Tucson Division
$200,000 over the 6 years, 1931-36.

During these years no major floods occurred. The average annual damage to railroads in this 6 and 11-year period is $84,000

B. Damage to Highways

Data on damage to highways cover, in some cases, the past year, in others the past 5 years, and in others the past 6 years. The entire highway system is covered but the time period is deficient. The annual average damage figure covering a period varying between the past 1 and 6 years equals $49,000

C. Damage to Industrial and Municipal Property

The only such damage of which there is record is that which has occurred at Clifton and Morenci, although other similar damage seems likely to have occurred. The data on Clifton and Morenci is

itself not definitely established as complete. From 1880 to date flood damage at Clifton was as follows:

1880	$50,000	(1)
1891	100,000	(2)
1905	150,000	(3)
1906	150,000	(3)
1914-1915	50,000	(4)
1916	200,000	(5)
Total over 56 years	$700,000	

Damage has occurred almost entirely in years of major floods. The river bed at Clifton is now 14 feet higher than in 1916 and damage from future floods is therefore likely to be greater. While other damages have been reported, the only reliably recorded damage at Morenci has been to the water works on Eagle Creek. In 1916 this was damaged to the extent of $50,000.

Annual average damage from 1880 to date (56 years) at Clifton and Morenci $13,000

(1) Personal memoirs of Superintendent of Clifton Mines
(2) Newspaper account "The Solomonville Bulletin"
(3) Magazine account "The Copper Era"
(4) Newspaper account "The Arizona Republican"
(5) Nospaper and magazine accounts "The Copper Era" "The Arizona Republic" and "The Graham County Guardian"

D. Destruction of Cultivated Land

Exact data on the loss of cultivated land are available for the Safford and Duncan Valleys. Such loss has occurred elsewhere but there are neither surveys nor records to indicate its extent.

Such destruction as has occurred has been by way of bank cutting during flood flows, and has been observed during floods of relatively small magnitude.

1. Safford Valley

Area in river bed in 1875	930 acres	(1)
Area in river bed in 1935	10860 acres	(2)
Loss in land (60 years)	9880 acres	

Land was irrigated and cultivated up to the edge of the river so that all that lost was cultivated irrigable land now valued at $200 per acre. Total loss: $1,976,000.

2. Duncan Valley

Loss in acres	1450 acres	(3)
Total loss	$290,000	

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(1) Survey of U. S. Land Office, 1875

(2) Aerial Survey of Soil Conservation Service, 1935

(3) Local information

Approximately 72,000 acres of cultivated land remain in the Safford Valley, and 9,000 in the Duncan Valley. This entire acreage is susceptible to destruction by bank cutting at an accelerating rate.

Total Annual Average Loss of Cultivated Land in Safford and Duncan Valleys, during 60 years $38,000

E. Damage to Irrigation Works (Canals, Dams, etc.) From Flooding

During major floods in the past irrigation works have regularly been destroyed. In every year a certain amount of damage has occurred. Data on the expenditures for repairs are available only for a section of the Safford Valley, the 7,000 acres under the San Jose and Montezuma Canal Companies. On the basis of these data (1) the following conservative estimates of damages of this type were made:

1. Safford Valley

For the 5 Major Flood Years Between 1891-1916

1891	$ 50,000
1905	200,000
1914	130,000
1915	165,000
1916	200,000
	$754,000

(1) In minutes of Joint Meeting of Stockholders of San Jose and Montezuma Canal Companies, 1936.

For the remaining 21 years between 1891-1916 on the basis of an approximate yearly average of $34,000

$705,000

For 20 years 1916-1936 on the basis of a yearly average of $50,000

$1,000,000

Total loss during 46 years $2,450,000

2. Duncan Valley

On the same basis, but making allowances on the basis of the knowledge that damage has been less severe in this area, the total loss from 1891 to date in the Duncan Valley is estimated at $300,000.

No data are available for other agricultural areas.

The total annual average damage of this type for the area as a whole is estimated then at $61,000

F. Damages to Crops From Flooding, Silt Deposition

A certain amount of data on damage of this type in the Safford Valley is available.(1) Losses of this type have occurred only during major floods. On the basis of this data the following estimates of damage of this type in Safford Valley are made:

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(1) Newspaper Reports; Water Supply Paper. 162.

1. Safford Valley

1891	$ 35,000
1905	100,000
1906	25,000
1915	10,000
1916	60,000
Total (46 years)	$230,000

2. Duncan Valley

On the same basis total damage of this type from 1891 to date in the Duncan Valley is estimated at $30,000.

Total Annual Average Damage Safford and Duncan $6,000

G. Reduced Crop Production Resulting From Destruction and Silting of Canals and Diversion Dams

The destruction by floods and silting of canals and diversion dams has resulted in lack of water for crops during the growing season, with a consequent loss in production. In certain years there has been a total loss of crop. It is estimated that losses of this type in the Safford Valley in the 46 years since 1891 have totalled $5,000,000. Estimated loss for the Duncan Valley during the same period is $130,000.

Average Annual Loss Safford and Duncan $112,000

H. Costs of Silting of Canals and Lands on San Carlos Project

The necessary use of flood waters from the San Pedro results in continued silting of canals and lands on the San Carlos project. It compels annual expenditures for the clearing of main canals by the irrigation district, and of individual ditches by individual operators; expenditures for the re-levelling of land; and it results in reduced yields of alfalfa. The following are estimates of the annual costs resulting from the use of the silty water:

Cost to district of clearing of main canal	$50,000
Cost to individual operators of clearing ditches (50¢ per acre average)	$37,500
Increased levelling costs (50¢ per acre average)	$37,500
Reduced yield of alfalfa (1 ton loss, 20,000 acres @ $7.00 per ton)	$140,000
Total Average Annual Costs	$265,000

Note on Costs of Silting of Canals and Lands on San Carlos Project

A divergence of expert opinion exists concerning the basic agronomic facts involved in these calculations.

Recently a re-examination of this subject was undertaken by Mr. J. C. Hamilton, Chief Agronomist of the Gila District, Soil Conservation Service. In the course of this rechecking of certain earlier estimates Mr. Hamilton has consulted with the following residents of the San Carlos Project: District Engineer and Water Master of the Water Users' Association, a Representative of the Saxton Experiment Station, the County Agricultural Agent, and others.

A summary of Mr. Hamilton's report (1) is as follows:

1. "Clear water carrying only a nominal supply of silt is more valuable than the San Pedro flood water that carries excess quantities of colloidal silts.

2. "Silty water is beneficial to new and porous soil for from one to five years but is detrimental after this time.

3. "San Pedro silt changes the physical structure of the soil, but in no case does it add to the fertility.

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(1) Memorandum to Robert V. Boyle on the Subject of Silt Damage From San Pedro, May 17, 1937

4. "Existing San Pedro flood water silt results in:

   a. "Increased cultivation and irrigation costs on cultivated lands."

   b. "Reduced yield and quality of alfalfa hay equal to or exceeding one ton per acre per season."

   c. "Lowering of water permeability of the soil."

1. Damage to Range Lands

The continuing process of erosion on the range lands of the Upper and Middle Gila Watershed is resulting in a progressive depletion of forage production on these lands. This damage might be measured in terms of reduction of the livestock carrying capacity of the watershed range lands. However, no detailed estimates based on range surveys of carrying capacity at any time in the past are available. It is known that the number of livestock now supported by these range lands is considerably less than in times past.(1) It has been estimated, also, that the average forage depletion of the semi-desert grass type, which is predominant in the Gila area, is approximately 55 per cent. The major part of this depletion has probably occurred since 1870 when "livestock grazing on a large scale started in the Gila country"(2). The quantitative significance of the damage is roughly indicated by the estimate quoted. No attempt is here made, however, to convert this estimate into monetary terms.

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(1) "The Western Range", Senate Document No. 199, 1936, page 110.

(2) "Report of the Upper and Middle Gila Watershed", Soil Conservation Service, 1937, page 22.

J. Problems of Damage Resulting From the Silting of the San Carlos Reservoir

The rate of silting of the San Carlos Reservoir was investigated in 1935 by M. M. Eakin. He found that during the 6-1/3 years of its operation the reservoir had accumulated an average of 5,829 acre-feet of silt per year, that the annual draft for irrigation had averaged 246,372 acre-feet per year, and that, at that rate of filling, 165 years would be required to reduce capacity to the average annual draft.(1)

The records of precipitation and run-off in the Gila watershed indicate, however, that the 6-1/3 years covered by the survey were years in which run-off in the Gila was below average and that, therefore, the rate of sedimentation of the Reservoir was lower than average. For purposes of projection into the future, therefore, it has been deemed advisable not to use Eakin's figures as representative of a long-time average rate of silt accumulation, although they measure accurately silt accumulation during a period of low run-off.

This problem is discussed in Supplement I to the Gila Report, page 145, and the average annual delivery of silt

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(1) "Silting of Reservoirs", Technical Bulletin 524, U.S.D.A., pages 96, 97.

to the reservoir is computed as 10,760 acre-feet. For the purpose of the present calculations, this latter figure is adopted.

At the time of the survey reported by Eakin, not all of the present acreage in the project was under irrigation. The annual draft figure of 246,000 acre-feet is based on the quantity of water used for that acreage during the low water years. The present estimated necessary annual draft is 320,000 acre-feet and this figure is, therefore, adopted for purposes of calculation. It is estimated, also, that on account of the yearly and cyclical variations in precipitation and run-off, a water storage capacity of at least 800,000 acre-feet is required to insure sufficient water for irrigation purposes each year. On the basis of these figures, at the present rate of silting the water storage capacity will be reduced within approximately 40 years to a point at which there will no longer be certainty of an adequate water supply each year; that is, to less than 800,000 acre-feet. Within approximately 80 years the water storage capacity will be reduced to the annual draft for irrigation purposes, and water shortage will be frequently experienced. Within approximately 110 years the water storage capacity will be entirely depleted. At some point around or prior

to the end of 80 years, the construction of a new dam and reservoir will be necessary if the present acreage is to remain in cultivation.

The Gila Flood Control Report contains a discussion of excess evaporation due to the silting of the San Carlos Reservoir, and a graphic delineation of the volume of water loss by evaporation which will result from continued silting. Since a consideration of this process is contained in any calculation designed to estimate the effective life of the existing reservoir, no separate evaluation of this loss need be made.

If it is assumed that there are other possible sites on the river for a dam and storage reservoir, then, it seems clear, the value of the damage from silting of the present reservoir is represented by the cost of its replacement. Eakin comments on this question as follows:(1)

"The view, all too frequently held, is that the destruction is to be measured by the cost of the original reservoir. This could be so only where additional storage could be developed indefinitely and at similar cost. There is, of course, an ultimate limit of feasible storage in every watershed. It is only natural that the initial reservoirs should be constructed at the .

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(1) "Silting of Reservoirs", Technical Bulletin 524, U.S.D.A., July, 1936, page 3.

most favorable and economic sites, and that substitute or supplementary storage facilities to serve the same locality are more costly. It is, therefore, probably correct to compute the more immediate harm of reservoir silting upon the basis of replacement rather than original storage costs and the ultimate harm in terms of the entire economic development dependent upon local water storage." For the purpose of the present calculation, damage resulting from the silting of a reservoir is considered, essentially, as impairment of capital value of productive equipment. The monetary measure of this impairment of value is taken to be the cost of replacement. The cost of replacing the storage capacity of the San Carlos Reservoir is estimated at $25 per acre-foot,(1) or a total of $30,000,000. If 80 years may be taken as the period over which its capital value will be completely dissipated then the average annual impairment of value, or damage is $375,000

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(1) On the basis of surveys of dam sites and estimates of costs by the Soil Conservation Service, as reported in "Recommendations for Flood Control of the Upper and Middle Gila River in Arizona and New Mexico", 1935.

GENERAL DAMAGES

In addition to the foregoing specific damages there are many damages of a general nature resulting from floods and erosion, whose monetary value cannot, in this case, readily be estimated. The general significance of these damages may be indicated here.

TRANSPORTATION AND COMMUNICATION

The Upper and Middle Gila Watershed lies directly in the path of the southern transcontinental lines of transportation and communication. These railroads and highways traverse the entire watershed. Interruptions and delays of traffic recur constantly.(1) The cost of these damages is not measured by the cost of repairs to highways, railroads, and bridges. No technique has as yet been developed for the measurement of the losses suffered by those dependent upon these lines of transportation and communication. Until such a technique is developed it is possible to indicate only that such losses annually are enormous but cannot be estimated in monetary terms.

BUSINESS AND HUMAN VALUES

The losses resulting from the destruction of cultivated land in the irrigated valleys and from depletion of

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(1) See preceding tabulation and summary of damages from records of Weather Bureau.

range lands in the Upper and Middle Gila Watershed have been discussed above. The former loss was taken account of in terms of the current market value of the land. The estimate derived in this manner, however, does not encompass the total loss resulting from this type of damage. In the small towns and trade centers of the area there exists an economic development dependent almost entirely upon the productive use of these lands. The only other productive activity in the area is mining, in which a small portion of the working population of the area is employed. Only a very minor part of the business and service structure of the towns exists by virtue of the mining activity of the area.

The business and urban values of the area are entirely derivative from and secondary to the basic productive activities of the area. The destruction of irrigated land and the depletion of range lands result in the destruction of the market upon which the business and service activities of the area depend, and the consequent destruction of their value. No technique has as yet been evolved for the evaluation of this loss and no monetary estimate can, therefore, be presented.

Examination of assessed valuations in the watershed indicate that a ratio of approximately one to one obtains

between the total value of irrigated and grazing lands and their improvements on the one hand, and the total value of urban properties on the other hand. This ratio suggests that, in the long run, for every dollar of rural values lost an equal amount of urban values may be lost. So many complex factors are involved in this problem, however, that no attempt is made here to use this simple ratio for developing monetary estimates of this type of general damage.

It should be noted, also, that the damaging effects of the depletion or destruction of land resources in an area as large as the watershed of the Upper and Middle Gila extend beyond the area itself to the economic structure of at least the entire state. In a state where the forms and extent of economic activity are so relatively limited, specific damage to a single area may be accompanied by damaging reverberations in the state tax structure and in business activities throughout the state.

DAMAGE TO DISTANT AREAS

The report on proposed Gila flood control measures lacks basic data relevant to the contribution of floods originating on the Upper Gila to floods on the lower Gila and Colorado rivers. Nevertheless, it is a certainty that some part of the flood damages which have occurred in the

lower Gila, Yuma, and Imperial Valley areas is attributable to floods originating on the Upper Gila. In the absence of detailed data, however, it is not possible to make a monetary estimate of these damages.

TABULAR SUMMARY OF AVERAGE ANNUAL DAMAGES

Specific Damage to:	
Railroads	$ 84,000
Highways	49,000
Industrial and Municipal Property	13,000
Cultivated Land	38,000
Irrigation Works	61,000
Crops	6,000
Crop Production	112,000
Land and Canals on San Carlos Project	265,000
Range Lands	--
San Carlos Reservoir	375,000
General Damage to:	
Transportation and Communication	--
Business and Urban Values	--
Lower Gila and Colorado Areas	--
	$1,003,000

Note: The above estimates are approximate, incomplete and accurate only within wide limits.

CALCULATION OF BENEFITS

The following calculation of benefits to accrue as a result of the proposed flood control work is based upon the assumption that the past period covered by the record of damages presented above is an average period, and that, therefore, the average annual damages in the future, in the absence of any flood control work, will be similar to the average annual damages in the past. A large part of the benefits will consist of the prevention of various types of damage that occur as a result of floods and erosion. These benefits are discussed in terms of the categories of damage listed above.

Reduction of Damage Due to Flooding (Railroads, Highways, Industrial and Municipal Property, Irrigation Works, Crops, Crop Production)

It is indicated (1) that the proposed program of watershed treatment will materially affect flood flows, but that "trunk stream treatment such as dams, levees, and revetments would be required" for additional protection. Such trunk stream treatment is to be recommended by the War Department and, it is assumed, will be sufficiently effective to completely eliminate all damage

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(1) Report on the Upper and Middle Gila Watershed, Supplement I, pages 89, 90, 92.

to railroad, highways, industrial and municipal property, irrigation works, crops and crop production.

Estimated average annual benefits (1) $325,000

Reduction of Damage to Cultivated Land

It is indicated (2) that the proposed watershed treatment in conjunction with "some structural work in the channel" will assure complete protection to the upper valley irrigated lands.

Estimated average annual benefits (3) $38,000

Reduction of Damage Due to the Silting of Canals and Lands on San Carlos Project

It is estimated (4) "that the treatment of the San Pedro watershed lands as proposed would eventually be effective in reducing its silt discharge by about forty per cent. A flood control dam at the Riverside #2 site would be effective in further reducing the transportation of San Pedro silt to the San Carlos irrigation district, but it is not possible to make the estimate in

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(1) See Summary of Damages, A, B, C, E, F, G.
(2) Supplement I, pages 90,91
(3) See Summary of Damages, D
(4) Supplement I, page 85

in quantitative terms."

In the absence of any figure on the effectiveness in this respect of the Riverside #2 dam, the figure of forty per cent is here used in calculating the extent to which this type of damage will be reduced. This figure may be revised when the necessary data are available.

Estimate average annual benefit $106,000 (1)

Reduction of Damage to Range Lands

Depletion of forage on range lands in the watershed has proceeded to the point where the present carrying capacity is approximately 170,000 livestock units.(2) It is estimated that the proposed watershed treatment "will result in a permanent carrying capacity equal to the present stocking".(3) The present stocking is approximately 196,000 livestock units. Carrying capacity will be increased, therefore, by an estimated 26,000 livestock units.

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(1) See Summary of Damages, B.

(2) According to surveys of the Soil Conservation Service and Forest Service and the Compilation of the Range Management Section, Gila District, Soil Conservation Service.

(3) Supplement I, page 80.

It is assumed by range experts that a given amount of forage on a range can be converted into no more and probably less meat and income by an excess number of animals than by a proper number. While there is as yet insufficient empiric evidence to completely substantiate this assumption, it appears sufficiently logical to be used in the calculation of benefits from increased carrying capacity. That is, we may assume that the present annual income from the livestock in the watershed is no greater than that which would be derived from the smaller number of livestock equivalent to the carrying capacity of the range. The present annual income from livestock in the watershed is approximately 1,600,000, (1) or $9.40 per unit of livestock carrying capacity. The estimated future carrying capacity is 26,000 livestock units higher. The estimated increase in annual income from livestock, then, is $250,000.

Estimated average annual benefit $250,000

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(1) According to compilation of Range Management Section, Gila District, Soil Conservation Service.

Reduction of Silting of San Carlos Reservoir

The supplement to the Report on the Upper and Middle Gila Watershed contains a number of estimates of the length of time required to achieve maximum effectiveness of the proposed program.(1) Calculations relating to the anticipated silt reduction effect of the proposed program are given for ten years and for stabilized condition. No special time period is indicated for stabilization, but 40 and 50 years are the longest periods discussed. On the basis of these calculations it is estimated that after ten years the amount of silt entering the San Carlos reservoir will be reduced to 4870 acre feet per year, and after another period of years, 50 at the outside, to 3,100 acre feet per year.(2) At this rate the water storage capacity of the reservoir will not be reduced to what is considered safe storage capacity, 800,000 acre feet, until the end of approximately 90 years. Not until the end of approximately 230 years will the capacity be reduced to the necessary annual draft of 320,000 acre feet.

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(1) Supplement I, Supplement II.

(2) Supplement II, pages 155, 156.

If the point at which the reservoir capacity is reduced to the annual draft is taken as the point at which complete replacement of the water storage plant is necessary, then the proposed control measures will, according to the above estimates, extend the life of the present reservoir from 80 to 230 years.

In terms of benefits the significance of this extension is that the necessity for an investment of $30,000,000 (1) will be deferred for 150 years. The cost of this investment at 3% interest is $900,000 per year. The total saving, or benefit, then, will be $900,000 for 150 years, or $135,000,000. This total benefit will accrue over a period of 230 years, the total life of the present reservoir. The average annual benefit, then, over the next 230 years will be approximately $587,000. (2)

Estimated average annual benefit (230 years) $587,000

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(1) See Summary of Damages, D.

(2) An alternative calculation is the following:

Present annual damage (see Summary of Damages) (Impairment of Capital)	$375,000
If life of reservoir is extended to 230 years:	
Annual impairment of capital	$130,000
Annual saving or benefit, then	$245,000

Benefits from Increased Electric Power Development at Coolidge Dam

Among the recommendations presumably to be made by the War Department[1] is that for the construction of a dam at the Riverside #2 site, with a storage capacity of 320,000 acre feet. A portion of this capacity is to be allotted for water released from Coolidge Dam in the development of electric power. At the present time efficient utilization of power production facilities at Coolidge Dam is not possible because water cannot be released except when needed for irrigation. The construction of the Riverside #2 Dam will permit efficient utilization of these facilities and a consequent increase in power revenues. The amount of the increase is estimated at $24,000 annually.[2]

Estimated average annual benefit $24,000

Benefits From Additional Stored Water

The proposed Riverside #2 Dam will store annually, it is

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(1) Assuming general adherence by the War Department to the Supplement to Report of Recommendations for Flood Control of the Upper and Middle Gila River, Soil Conservation Service, 1935.

(2) Letter of February 2, 1937 from C. H. Southworth, Assistant to Director of Irrigation, Office of Indian Affairs, to C. W. Collier, Soil Conservation Service.

estimated[1] approximately 33,000 acre feet of flood water which cannot now be diverted for irrigation of San Carlos Project lands. This stored water is estimated to have a value for irrigation purposes of approximately $9.00 per acre foot, on the basis of the gross value of crop production per acre foot of water on the San Carlos project. The total annual value of 33,000 acre feet of additional stored water, then, is approximately $297,000.

Estimated Average Annual Benefit	$297,000

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(1) Supplement to Report of Recommendations for Flood Control of the Upper and Middle Gila River in Arizona and New Mexico, 1935, Soil Conservation Service, page A-21.

GENERAL BENEFITS

In addition to the specific benefits listed above, there are general benefits of great significance. These are benefits resulting from the reduction of the several types of general damage discussed above.(1) No means are available, however, for making a monetary estimate of these benefits. It can merely be stated that the prevention of interruptions of transportation and communication, the reduction of flood flow contributions to the lower Gila and Colorado, and the prevention of indirect and general loss to business and urban values are significant items of benefit. They cannot now be accurately measured but should not be overlooked.

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(1) See Summary of Damage.

TABULAR SUMMARY OF AVERAGE ANNUAL BENEFITS

Specific Benefits from:	
Reduction of Damage Due to Flooding	$ 325,000
Reduction of Damages to Cultivated Land	38,000
Reduction of Damage to San Carlos Project Lands	106,000
Reduction of Damage to Range Lands	250,000
Reduction of Damage due to Silting of San Carlos Reservoir	587,000
Increased Electric Power Revenue	24,000
Additional Stored Water	297,000
General Benefits from:	
Prevention of Interruption of Transportation and Communication	-
Prevention of Loss to Business and Urban Values	-
Reduction of flood flow contributions to lower Gila and Colorado	-
	$1,627,000

Note: The above estimates are approximate, incomplete, and accurate only within wide limits.

CLASSIFICATION OF BENEFITS

Benefits may be classified or segregated in a number of ways. In the following classifications those unestimated general benefits mentioned above accruing to the public at large or to distant areas are not considered.

The following is a classification of benefits in terms of the type of proposed work responsible for them:

Benefits attributable to watershed treatment alone	$ 356,000
Reduction of Damage to San Carlos Project Lands	
Reduction of Damage to Range Lands	
Benefits attributable to trunk stream work alone (Riverside Dam #2)	$ 321,000
Increased Electric Power Revenue	
Additional Stored Water	
Benefits attributable to combination of watershed treatment and trunk stream work, but not to either one alone	$ 950,000
Reduction of Damage Due to Flooding	
Reduction of Damage to Cultivated Land	
Reduction of Silting of San Carlos Reservoir	
TOTAL:	$1,627,000

Another classification of benefits follows:

Benefits accruing to San Carlos Project	$1,014,000
Reduction of Damage to San Carlos Project Lands	
Reduction of Silting of San Carlos Reservoir	
Increased Electric Power Revenue	
Increased Stored Water	
Benefits accruing to Upper and Middle Gila Area	$ 613,000
Reduction of Damage Due to Flooding	
Reduction of Damage to Cultivated Land	
Reduction of Damage to Range Lands	

Of the total benefits accruing to the San Carlos Project, approximately one-half may be considered a direct benefit to the United States Government since it or its wards, the Indians, own half the lands and storage and irrigation works of the San Carlos project.

Some portion of the other half of the benefits accruing to the San Carlos Project may be considered an indirect benefit to the United States Government since it is conceivable that in the absence of these benefits the non-Indian participants in the San Carlos Project would fail to pay their entire share of the cost of the project.

RATIO OF BENEFITS TO COSTS

This report does not attempt to develop a statement of the "economic justification" for the Gila flood control proposals. The material presented is intended to provide the basic data from which a ratio of average annual benefits to average annual costs may be calculated for purposes of comparison with other flood control projects.

Certain of the data essential to the preparation of such a ratio for the Gila flood control proposals are, however, not available. Data on estimated average annual benefits are available. These are estimated at $1,600,000. Certain of the necessary cost data are lacking.

Average annual costs are taken to be the annual interest on the initial cost plus the annual operation and maintenance cost. Since average annual costs are here calculated only for use in a comparative benefit-cost ratio, amortization of initial cost need not be considered. For comparative purposes the annual interest on this cost affords the same measure as would interest plus amortization, so long as amortization is spread over the same period of years as are benefits. This same procedure was used in developing a ratio of average annual benefits to average annual costs by the Mississippi Valley Committee. (1)

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(1) See "Analysis of Costs and Benefits", Page 153 of Report of the Mississippi Valley Committee of the Public Works Administration, 1934.

The report estimates total initial costs of all proposed work at $27,000,000.[1] The annual interest on this amount at three per cent is $800,000. No estimate of the annual operation and maintenance cost of the watershed treatment proposed by the Soil Conservation Service is contained in the report. The recommendations of the Army Corps of Engineers are not yet submitted so that data on the annual operation and maintenance cost of the trunk stream work to be proposed are also not available. It is therefore possible to present only a partial estimate of average annual costs, $800,000. The ratio of estimated benefits to estimated partial costs is approximately two to one. This ratio, however, has no significance in view of the fact that it is incomplete. It may, however, be revised upon acquisition of the necessary data on operation and maintenance costs. Subsequent to the indicated revision, this ratio may be used to determine the place of the Gila flood control proposals in a national program of flood control.

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(1) Table III, following page 31, "Report of the Upper and Middle Gila Watershed with Proposals for Erosion Control and Waterflow Retardation", Soil Conservation Service, 1937.